- ***Who is in your cohort and what are your teaching contexts?***

There are four of us in this cohort, all teaching algebra. Jan teaches college algebra at a university, Mark teaches college algebra at a community college, Shanna teaches intermediate algebra at the community college, and Mario teaches algebra 2 at a high school with a high proportion of students eligible for free and reduced price lunch. The community college and university have a high proportion of first generation college students compared with other colleges in our state. All of the algebra classes taught by instructors in this cohort contain between 23 and 31 students. Each class contains a variety of under-prepared students to well-prepared students.

- ***Briefly describe yourselves professionally.***

Jan: I have been teaching as a university lecturer for six years, and taught high school mathematics for eight years before moving to the university. I've been in another project, the Transition Mathematics Project, in which I worked with others to discuss common expectations for students moving from high school to college. I have been most interested in how to get students to take responsibility for their learning. When I observed the others in my cohort, we had frank discussions about how different high school and college is for students in that high school teachers can often change their schedules to spend more time on a topic if students aren't "getting it," but college instructors expect students to come to their office hours or go to the math lab when they are confused.

Mario: I am a fairly new high school teacher, teaching just 4 years, although I have been involved in a professional learning community with other algebra teachers in my district. I am interested in helping students develop "deep learning" strategies so they have strategies to understand the math. Our district math coordinators have also been helping us use rich tasks at least once a week, and I have found that motivating kids to persevere on these tasks is a real challenge. When I observed the others, it was clear that students needed to know how well they understood the concepts, so have some deep learning strategies, and perseverance in order to be responsible for their own learning.

Mark: I've been teaching at the community college for more than 24 years, but this is the first project I've been in that I have worked with instructors from other institutions. I was really excited about what I saw when I went to both the high school and university. Our students are really very similar, but I learned several ideas about being explicit with my students about what I expected from them. For example, Mario didn't just do the homework problems when students asked questions, but probed to find out what they had tried and what they were thinking. Then, he had them work in groups to answer their own and others' homework questions.

Shanna: I've been teaching at the community college for 7 years, and haven't been in any other formal projects, but have collaborated closely with colleagues when we've changed curriculum and approaches. It has been so helpful in this cohort to work with others who share my concerns about students' difficulties and how to motivate students to aim for understanding the connections in math instead of just getting a right answer. I noticed that in Jan's class, she really got students to continue working on a problem when they had not seen a problem like it. I heard the students in her class discussing problems in groups. Some of the students were really trying to understand in the ways that I would like my students to understand.

- ***What significant problem of practice did your intervention target?***

We decided to work on the problem that students do not seem to strive for deep learning strategies. We picked it because it seemed to be the problem that best described all of our concerns. Our more specific problem was to try to get students to understand and explain the mathematical ideas and connections clearly to themselves or others. This is about building conceptual understanding while also using correct vocabulary. We think that if students build the skills to explain problems to themselves and others, explain solutions with good mathematical reasons, using correct mathematical vocabulary and notation, they could be more independent learners in college and also work well in groups in college. The evidence we had in each of our classes varied. Only one of us regularly asked students to explain their reasoning on tests or quizzes. We agreed, for the most part, that we do not give our students enough chances to explain their thinking in writing. We shared some student work in an early workshop and noticed that many of our students described procedures without reasons when asked to explain. Many of them used the wrong vocabulary, too.

- ***What CCSS relate to this problem and how (including portraits and math practices)?***

SMP 1: students start by explaining to themselves the meaning of a problem;
SMP 3: students build arguments and critique the reasoning of others; and,
SMP 6 : students communicate precisely, using clear definitions in their own reasoning and making explicit use of definitions.

- ***What scholarship (articles, books, reports) did you consult and how did it inform your project?***

Baxter, J. A., & Woodward, J., & Olson, D. (2005). Writing in mathematics: An alternative form of communication for academically low-achieving students. *Learning Disabilities Research & Practice, 20*(2), 119-135.

Burton, L., & Morgan, C. (2000). Mathematicians writing. *Journal for Research in Mathematics Education, 31*(4), 429-453.

Draper, R. J., & Siebert, D. (2004). Different goals, similar practices: Making sense of the mathematics and literacy instruction in a standards-based mathematics classroom. *American Educational Research Journal, 41*(4), 927-962.

Pugalee, D. K. (2004). A comparison of verbal and written descriptions of students' problem Solving processes. *Educational Studies in Mathematics, 55*(1/3), 27-47.

Shield, M. & Galbraith, P. (1998). The analysis of student expository writing in mathematics. *Educational Studies in Mathematics, 36*(1), 29-52.

- ***What intervention did you test and how did each person in your cohort try it?***

We each created four assignments over eight weeks in which we asked our students to write about their solutions to challenging problems, giving full explanations about their thinking and mathematical justifications of their work. We gave students a rubric that we developed based on the literature and our own ideas about deep learning, and went over it in class to help them understand the meanings of the different parts. We had students do some of the assignments in class and others for homework, with the college instructors giving more of the writing assignments for homework than in class.

- ***How did you determine the effectiveness of your intervention?***

We met after giving and scoring the first assignment. When we met, we each brought the assignment, select student work that showed different levels of work on the rubric, themes that we saw in how students responded to the assignment, challenges we noticed, and the scores of all the students in one class on the assignment.
We continued to meet and discuss how to overcome some of the challenges we saw after each assignment and scoring.
In the end, we agreed that the experiment was very worthwhile, both for students' learning and for our own.

- Students' scores on writing about their solutions improved over the four uses of the rubric.
- More students seem to be answering and asking questions in class, and seem to give longer explanations.
- We don't know if students value the deeper learning strategy yet, and wish we had some sort of assessment to use pre and post to help us measure this.
- More of our results are discussed in how students responded (below).

- **How did students respond?** (Anecdotal evidence is acceptable here.)

We each had some challenges in carrying out our plan. It takes more time to have students explain in writing, and students at all levels complained that they didn't think they should have to write in math class. However, we each explained to our classes how important it was and that it would help them in the long run, and most students accepted it.
In our early implementation, across all of our classes we found:

- Students struggle with problem solving and with writing, so having them combined in a single assignment presented a large hurdle for many students.
- While many students could finish the problems, they either could not explain why they could take some steps they did, or they incorrectly explained their solutions.
- Many students did not have the vocabulary they needed to explain their solutions, or used the wrong vocabulary.
- Many students initially explained only procedures,
- Some students had difficulties understanding the rubric,
- A few students are very poor writers so this seemed to make math class much harder for them, and
- From reading their solutions, we better understood some ways that students think about the math, and we could address certain ideas better.

We discussed the results of our first two assignments together, and improved the rubric. We agreed to give students examples of good explanations from other students. We also agreed to include a "peer review" on the third assignment. This involved having students read two other students' explanations, score them on the rubric, and give constructive comments to the writers. We also decided to have students solve the problem in class and discuss it as a class, then have them write their explanations for homework. This broke up the difficulties of solving a problem and writing about it all in one assignment. There was evidence that students improved their writing about their solutions after this. Here is what we learned:

- Some students did not understand the mathematics well enough, and did not have the perseverance to try to understand others' solutions, so did not write helpful comments.
- Most students seemed to improve their own explanations after reading and responding to others' work, probably because they better understood the rubric.
- This took quite a bit of class time, so in the future we would only use these larger writing assignments for the most important concepts we teach.
- A few students continue to resist this mode of learning. Their comments indicate that they see the writing assignments as extra work rather than a tool for improving their understanding. They do not seem to value understanding at a deeper level in mathematics.
- We think we should try more frequent but shorter writing assignments, and with more specific prompts, in order to prepare students for these longer explanations. The specific prompts should target particular areas of the rubric in order to prepare them for the larger assignments.
- We were each able to use students' explanations to target our teaching, so have come to value these assignments beyond their ability to prompt students' deep learning.

- **In what ways has your work changed your thinking about students' transitions or your teaching?** What do you still wonder?

In order to be successful in college, students need to take more ownership for their learning. We see how difficult it is to get them to do the work necessary for the type of learning that will help them be successful in math at any level. We wonder what other deep learning strategies we could help them develop, and if some of these strategies could more easily be taught and implemented in our classes than an approach through writing. We value the writing assignments and rubric, but think there may be intermediate strategies we should use first. We also wonder if there is a tool or way to measure students' deep learning strategies at the beginning of a course. We would like to try to develop a survey that measures this, and also a teacher observation tool.

Attached: Rubric, assignments from each of the classes, some student work that shows some of the issues that arose, our commentary on some of the student work.